What is the impact of liquids versus solid foods on energy intake and body weight?

Conclusion

A limited body of evidence shows conflicting results about whether liquid and solid foods differ in their effects on energy intake and body weight, except that liquids in the form of soup may lead to decreased energy intake and body weight.

Grade: Limited

Overall strength of the available supporting evidence: Strong; Moderate; Limited; Expert Opinion Only; Grade not assignable For additional information regarding how to interpret grades, click here.

Evidence Summary Overview

No consistent relationships have been reported between the form of a food and energy intake and body weight. This review included 12 studies with no consistent experimental designs. One study examined liquid calories to solid calories in the PREMIER trial (Chen, 2009). Six of the studies were crossover trials that investigated the impact of a preload before breakfast (Stull, 2008) or lunch (Almiron-Roig, 2004; Flood-Obbagy, 2009; Mattes, 2009; Mourao, 2007; Tsuchiya, 2006) on ad libitum intake of a meal. An additional crossover trial (Moorhead, 2006) examined the intake of carrots in various forms with a meal rather than as a preload. DiMeglio et al, (2000) conducted a longer term crossover trial that included two, four-week interventions with daily consumption of liquid (caffeine-free soda) or solid (jelly beans) food. Finally, three studies (Rolls, 2005; Flood, 2007; Bertrais, 2001) examined soup as the liquid form.

No standard protocol has been established to answer this question, and information on food form and consumption of liquid is not collected in prospective cohort trials. Most of the available evidence to answer this question is from preload studies, in which meals are controlled for total calories and macronutrient content, and then satiety is measured for three hours after the meal. Subsequent food intake is then measured by consumption of a buffet lunch and food intake for 24 hours may then be calculated.

In the one prospective study, Chen et al, (2009) examined beverage consumption in the PREMIER study at baseline, six months and 18 months. Analyses considered changes in volume, calorie intake and percentage of calories from beverages both overall and from seven categories [sugar-sweetened beverages (SSB); diet drinks; milk; 100% juices; coffee and tea with sugar; coffee and tea without sugar or with artificial sweeteners; and alcoholic beverages]. A reduction of 100kcal per day in liquid calorie intake was associated with an approximate 0.25kg weight loss at six and 18 months. In comparison, a reduction in solid calorie intake by 100kcal per day was associated with a less than 0.1kg weight loss at six and 18 months. Reductions in liquid calorie intake had a stronger effect on weight loss than did a reduction in solid calorie intake, but the difference was statistically significant only at six months. A significant dose-response trend between change in body weight and change in liquid calorie intake was observed at six and 18 months.

Consumption of solid food compared to juice in a controlled caloric load may decrease energy intake at a subsequent meal. Flood-Obbagy and Rolls (2009) examined how consuming preloads of apples in different forms (apple, applesauce and apple juice with and without added fiber) influenced energy intake of a meal. Study participants consumed fewer calories at lunch after consuming apples compared to equal calories as applesauce, apple juice or apple juice with added fiber. In a similar study, whole carrots were associated with less calorie intake for the remainder of the day compared to carrot juice or a carrot juice cocktail that contained all the nutrients in carrots (Moorhead, 2006).

Mourao et al, (2007) investigated the independent effect of food form on appetite and energy intake in lean and obese adults using high carbohydrate (CHO), fat or protein (PRO) food stimuli. Treatments were matched beverage and solid food forms: High CHO (watermelon and watermelon juice); high PRO (cheese and milk); high fat (coconut meat and coconut milk). Participants consumed the entire test food as part of an ad libitum meal. Regardless of the predominant energy source, the beverage form elicited a weaker compensatory dietary response than the matched solid food form. The authors concluded that inclusion of a caloric beverage in a lunch meal led to greater daily energy intake compared to customary intake or days where a solid version of the same food was ingested. This occurred regardless of the primary energy source, and there was no clear indication that the lean and obese differ in this regard.

Stull et al, (2008) assessed the effect of liquid vs. solid meal replacements on appetite and subsequent food intake in healthy older adults. After an overnight fast, participants consumed meal replacement products as either a liquid or as a solid (bar) followed byad libitum oatmeal. Participants consumed more calories from oatmeal after the liquid vs. solid meal replacement product.

Other studies suggest that food form may affect food intake, although inconsistent study designs make it difficult to compare results. DiMeglio and Mattes (2000) examined the differential effects of matched liquid (soda) and solid (jelly beans) CHO loads on diet and body weight. Participants were assigned to one of two dietary load conditions (solid: 450kcal serving of jelly beans; liquid: 450kcal serving of caffeine-free soda) for four weeks, followed by a four-week washout period and subsequent participation in the other condition for four weeks. During the solid load condition, participants compensated for some of the energy in the test foods by reducing free-feeding intake such that the overall compensation score was 118%. However, when the liquid load was included in the diet, no compensation was observed, resulting in a compensation score of -17%. The authors concluded that liquid CHO promotes positive energy balance, whereas a comparable solid CHO elicits dietary compensation; further, body weight and body mass index (BMI) increased only with the liquid load.

In contrast, both Mattes and Campbell (2009) and Almiron-Roig et al, (2004) found no differences in subsequent food intake when they compared solid food to liquids in studies well controlled for macronutrients and calories. Mattes and Campbell (2009) assessed the effects of apple food form (apple, applesauce, apple juice) and timing of eating events (meal or snack) on appetite and daily energy intake. There were no treatment effects on daily energy intake.

Almiron-Roig et al, (2004) compared the impact on energy intakes of equal-energy preloads (300kcal) of regular cola or fat-free cookies presented either two hours or 20 minutes before a tray lunch. Liquid or solid form had no impact on energy intakes during the test meal. Similarly, physical form had no effect when the sum of the energy intake of breakfast, preload and lunch was considered.

In another crossover trial (Tsuchiya, 2006) participants consumed 200kcal preloads: Semi-solid peach yogurt with peach pieces, peach yogurt homogenized to liquid form, peach syrup and water, or a milk-based peach and apricot beverage followed by an ad libitum lunch. No significant (NS) differences in energy intakes were detected across the four conditions, either for lunch alone or for total energy consumed from breakfast, preload and lunch.

Liquids in soup may have different effects as studies find that daily soup consumers have lower daily energy intake than those who consume little soup (Bertrais, 2001), and soup pre-loads reduce food intake at a subsequent meal (Flood, 2007). Rolls et al, (2005) tested the effect on weight loss of a diet incorporating one or two servings per day of foods equal in energy but differing in energy density. Participants followed an energy-restricted diet in a one-year trial (six-month weight loss and six-month weight maintenance); participants were randomized to one of four intervention groups. Participants were instructed to consume daily: One serving of soup, two servings of soup, or two servings of dry snack foods. Participants in the fourth group were not provided with any specific food to consume (comparison group). There were no significant differences in reported energy intake among the intervention groups at any time-points. All four groups showed significant weight loss at six months that was well maintained at 12 months. The magnitude of weight loss, however, differed by group. At one year, weight loss in the comparison (8.1±1kg) and two-soup (7.2±0.9kg) groups was significantly greater than that in the two-snack group (4.8±0.7kg); weight loss in the one-soup group (6.1±1.1kg) did not differ significantly from other groups. The authors concluded that on an energy-restricted diet, consuming two servings of low energy-dense soup daily led to 50% greater weight loss than consuming the same amount of energy as high energy-dense snack food.

When macronutrient content of a liquid food and a solid food is balanced, there are few data that food form affects energy intake. These studies are difficult to design and conduct as the form of the food cannot be blinded (i.e., participants know that they are eating apples or drinking apple juice). In the acute studies of food intake, efforts are made to control variables, including the time allowed to consume the test food, but it is difficult to generalize these results to the eating environment of real life.

Food structure may play a role in food intake. Whole foods, such as apples and carrots, play a role in satiety and decrease food intake at a subsequent meal. When a non-viscous fiber was added to apple juice, the fiber-enriched apple juice was not as effective as the apple in reducing food intake at a subsequent meal. Thus, factors besides the fiber in whole foods may affect energy intake, including food structure and chewing.

The data with soup as a preload are often in conflict with other data on liquid calories. In a one-year weight loss trial, consumption of two servings of soup per day led to greater weight loss than consuming the same amount of energy from two snack foods. Soup preload significantly reduced test meal and total meal energy intake in one study. Thus, the studies with soup as a liquid calorie source suggest that specific liquid calories can be an aid to weight loss and that liquid calories from soup result in reduced intake at a subsequent meal.

Evidence Summary Paragraphs

Liquid=Beverage

Chen et al, 2009 (positive quality), a prospective cohort study conducted in the US, examined how changes in beverage consumption affect weight change among adults. Participants were 810 adults (62% female; age 50.0±8.9 years; BMI=33.1±5.8kg/m^2) from the PREMIER study. Dietary intake was estimated by the average of two multiple pass 24-hour recalls conducted at baseline, six and 18 months to determine changes in volume, kcal intake, and percentage of calories from beverages both overall and from seven categories (SSB; diet drinks; milk; 100% juices; coffee and tea with sugar; coffee and tea without sugar or with artificial sweeteners; and alcoholic beverages). Weight and height were measured at each time-point. A reduction of 100kcal per day in liquid calorie intake was associated with a 0.25kg weight loss (95% CI: 0.11, 0.39; P<0.001) at six months and of 0.24kg

(95% CI: 0.06, 0.41; P=0.008) at 18 months; a reduction in solid calorie intake by 100kcal per day was associated with a 0.06kg weight loss (95% CI: 0.002, 0.14; P=0.04) at six months and 0.09kg (95% CI: 0.005, 0.16; P=0.003) at 18 months. Reductions in liquid calorie intake had a stronger effect on weight loss than did a reduction in solid calorie intake, but the difference was statistically significant only at six months (P=0.006). Similarly, a reduction in the percentage of liquid calories from total calories by 1% was associated with a weight loss of 0.04kg (95% CI: 0.01, 0.06; P=0.005) at six months and of 0.02kg (95% CI: -0.01, 0.06; P=0.02) at 18 months. When changes in consumption of liquid calories were divided into tertiles, a significant dose-response trend between change in body weight and change in liquid calorie intake was observed for both the six-month change (P=0.01) and the 18 month change (P<0.001). The authors concluded that their data support recommendations to limit liquid calorie intake among adults.

DiMeglio and Mattes, 2000 (positive quality), a randomized crossover clinical trial conducted in the US, studied the differential effects of matched liquid (soda) and solid (jelly beans) CHO loads on diet and body weight. Participants were 15 adults (53% female; age 22.8±2.73 years; BMI=21.9±2.2kg/m^2) who were assigned to one of two dietary load conditions (solid: 450kcal serving of jelly beans; liquid: 450kcal serving of caffeine-free soda) for four weeks, followed by a four-week washout period and subsequent participation in the other condition for four weeks. Dietary free-feeding energy intake was estimated by unannounced telephone 24-hour dietary recalls at baseline (three days) and six times during each treatment period and washout. Body composition was measured weekly. During the solid load condition, subjects compensated for the provided energy by reducing free-feeding intake such that the overall compensation score was 118%. However, when the liquid load was included in the diet, no compensation was observed; there was a slight increase in free-feeding intake such that the failure to compensate resulted in a score of -17%. Daily energy intake with the liquid load was significantly greater than intake with the solid load (P<0.001). Consequently, body weight and BMI increased significantly only during the liquid period. Body weight at the end of the liquid load period was significantly higher than at the beginning (P<0.05), although there was no difference between the change in body weight in the two conditions. BMI also increased significantly over the liquid load period (P<0.05), but the change was not different from that with the solid load. The authors concluded that liquid CHO promotes positive energy balance, whereas a comparable solid CHO elicits precise dietary compensation; further, increased consumption of energy-yielding fluids may promote positive energy balance.

Mourao et al, 2007 (neutral quality), a crossover dietary challenge, investigated the independent effect of food form on appetite and energy intake in lean and obese adults using high CHO, fat or PRO food stimuli. Treatments were matched beverage and solid food forms: High CHO (watermelon and watermelon juice); high PRO (cheese and milk); high fat (coconut meat and coconut milk). Participants were 120 lean (N=60; 18-23kg/m^2) and obese (N=60; 30-35kg/m^2) adults (18-50 years old) with stable body weight. Forty different participants (N=20 lean and 20 obese) were tested with each of the food systems. Each participant came to the lab on three test days (control, beverage, and solid). The lean participants were provided 125 kcal of test food and the obese participants were provided 225kcal of test food. Participants ate their breakfast followed by a three-hour fast before reporting to the lab for lunch. Participants were instructed to consume the entire test food as part of an ad libitum meal. Food records were kept each testing day to determine energy intake. Regardless of the predominant energy source, the beverage form elicited a weaker compensatory dietary response than the matched solid food form. Thus, total daily energy intake was significantly higher by 12.4, 19 and 15% on days the beverage forms of the high-CHO, -fat and -PROn foods were ingested, respectively. Differences between lean and obese participants were small and not systematic. The authors concluded that inclusion of a caloric beverage in a lunch meal led to greater daily energy intake compared to customary intake or days, where a solid version of the same food was ingested. This occurred regardless of the primary energy source, and there was no clear indication that the lean and obese differ in this regard.

Mattes and Campbell, 2009 (positive quality), a randomized crossover study conducted in the US, assessed the effects of food form (solid, semi-solid, or beverage) and timing of eating events (meal or snack) on appetite and daily energy intake. Participants were 20 normal weight (50% male; BMI=22.6±1.8kg/m^2; age 21.6±2.1 years) and 20 obese (50% male; BMI=32.3±1.5kg/m^2; age 25.6±5.9 years) adults. On six occasions, participants reported to the laboratory for a fixed portion mid-day meal. In addition, participants consumed 300kcal loads of a solid (apple), semi-solid (applesauce) and beverage (apple juice) at the meal or two hours later (snack). Diet recalls were collected the next day. The form of the food load had NS effect on energy intake at the first eating occasion of >100kcal after ingestion of the experimental meal and the load whether consumed with the meal or two hours after. There were no treatment effects on daily energy intake. There were NS differences between lean participants and those with obesity for daily energy intake. Although the authors noted different appetitive findings for the different food forms, these appetitive effects did not translate into differences in energy intake.

Flood-Obbagy and Rolls, 2009 (positive quality), a randomized crossover trial conducted in the US, examined how consuming preloads of apples in different forms prior to a meal (apple, applesauce, and apple juice with and without added fiber) influences satiety and energy intake at a meal. Once a week for five weeks, 58 adults (52% male) consumed one of four apple preloads (266g; 125kcal), or no preload (control), followed by a test meal consumed ad libitum 15 minutes later. All foods and beverages were weighed before and after being served to participants. Consuming apple significantly reduced total energy intake at lunch (preload and test meal) by 91±24kcal compared to consuming applesauce, by 152±36 compared to apple juice with fiber and by 178±27 compared to apple juice without fiber (all $P<0.02$). Lunch intake was significantly lower when applesauce was consumed compared to both types of apple juice ($P<0.05$); in the two juice conditions, however, total energy intakes at lunch did not differ significantly from each other. Compared to when no preload was consumed, subjects reduced total energy intake at lunch by 187±36kcal when apple was eaten, to 85±4% of intake in the control condition ($P<0.0001$). In addition, when applesauce was eaten as a preload, total energy intake at lunch was reduced by 96±29kcal compared to control ($P<0.01$). No significant difference in total energy intake at lunch was observed between the control (1,024±49kcal), apple juice with fiber (989±52kcal) and apple juice without fiber (1,015±51kcal) treatments. The authors concluded that consuming fruit before a meal can enhance satiety and reduce subsequent food intake, leading to a substantial reduction in total energy intake at the meal. In addition, the energy content of the apple juice both with and without fiber was compensated for by a reduction in subsequent intake; thus, drinking juice as a preload did not increase total meal energy intake.

Moorhead et al, 2006 (positive quality), a randomized crossover trial conducted in the United Kingdom, evaluated the effects of the fiber content and physical structure (gross anatomy and cell structure) of carrots on postprandial satiety and subsequent food intakes when consumed as part of a mixed meal. Thirty-six women (age: 33±7.03 years; BMI: 24.4±4.03kg/m^2) consumed a standardized breakfast and test lunches on three occasions, four weeks apart. The test lunches (3,329kJ) comprised boiled rice (200g) with sweet and sour sauce (200g) that included chicken (200g) and carrots (200g) in three conditions: Whole carrots (suspended in sauce), blended carrots (in sauce) or carrot nutrients (in sauce). All meals had the same energy, macronutrient, sodium, potassium, calcium and water contents, and the same weight and volume. Participants returned to the lab later in the day for an ad libitum afternoon meal that was weighed to determine intake. Participants then completed food diaries to estimate intake the remainder of the day. All subjected consumed the complete test lunches. There were significant differences between the three conditions for energy intake at the afternoon ad libitum meal (whole=1,669 (489) kJ; blended=2,247 (904) kJ; nutrients=2,881 (778); P<0.05). Similarly, energy intake for the remainder of the day was significantly lower for the remainder of the day for the whole and blended conditions compared to the carrot nutrient condition. The authors concluded that whole or blended carrots, eaten as part of a mixed lunch meal, result in significantly increased satiety and decreased subsequent intakes.

Stull et al, 2008 (neutral quality), a randomized crossover study conducted in the US, assessed the effect of liquid vs. solid meal replacements on appetite and subsequent food intake in healthy older adults. Participants were 24 adults (50% female; BMI=26.0±0.8kg/m^2; age=62±2 years) who completed two days of testing in random order and separated by one week. After an overnight fast, the subjects consumed meal replacement products as either a beverage (liquid) or a bar (solid). The meal replacement products provided 25% of each subject's daily estimated energy needs with comparable macronutrient compositions. At minute 120, each subject consumed cooked oatmeal ad libitum. The oatmeal bowl was weighed before and after eating to quantify amount consumed. On average, subjects consumed 13.4% more oatmeal after the liquid vs. solid meal replacement product (338±33 vs. 298±32kcal; P=0.006). The authors concluded that older adults consumed more food at the next eating occasion after consuming a liquid vs. solid meal replacement product.

Almiron-Roig et al, 2004 (neutral quality) compared the relative impact on satiety and energy intakes of the physical form of foods vs. the timing of consumption in a study with a within-subject design conducted in the US. Participants were 32 adults (50% female) aged 18 to 35 years. Average BMI for the men and women were 22.5±2.4 and 21.9±2.4kg/m^2, respectively. Participants consumed equal-energy preloads (300kcal) of regular cola (24-ounce) or fat-free raspberry cookies (three-ounce) on two occasions each for a total of four separate test sessions that were spaced at least a week apart. The order of presentation of the four preloads was counterbalanced across sessions. The preloads were presented either two hour or 20 minutes before a tray lunch. The same lunch foods were offered on all four testing occasions. All lunch foods were pre-weighed and plate waste was collected and weighed to determine food intake. Participants were also asked to record all the foods and beverages that they had consumed for breakfast that morning. Liquid or solid form had no impact on energy intakes [$F(1,30)=0.04$; $P>0.05$] during the test meal. Similarly, when the sum of the energy intake of breakfast, preload and lunch was considered, physical form had no effect [$F(1,30)=0.99$; $P>0.05$]. The authors concluded that energy intakes at lunch following the consumption of equal-energy amounts of cola or cookies were NS different.

Tsuchiya et al, 2006 (positive quality), a crossover study conducted in the US, compared the satiating power of semi-solid and liquid yogurts with fruit beverages and dairy fruit drinks. Participants (N=32; 50% female; BMI=22.9±1.9kg/m^2; age=27.1±4.7 years) consumed a 200kcal preload stimulus on four separate occasions separated by at least a week. The preloads were: Semi-solid peach yogurt with peach pieces, peach yogurt homogenized to liquid form, peach syrup and water or a milk-based peach and apricot beverage. A light breakfast was provided on arrival at the laboratory. The preload was provided 90 minutes later, and ad libitum lunch was provided 90 minutes after that. All foods were weighed when served and plate waste was collected and weighed. Mean energy intake (±SE) across the four conditions was 806±43kcal. No significant differences in energy intakes were detected across the four conditions, either for lunch alone or for total energy consumed from breakfast, preload, and lunch. Analysis of pooled dietary intake data for all subjects indicated that when yogurts were compared to the two beverages, energy intakes at lunch were lower (790±46 vs. 823±50kcal), but differences were NS. The authors concluded that lower hunger and higher fullness ratings after yogurt consumption were observed but did not lead to energy compensation at the next meal.

Liquid=Soup

Rolls et al, 2005 (neutral quality), a randomized controlled trial conducted in the US, tested the effect on weight loss of a diet incorporating one or two servings per day of foods equal in energy but differing in energy density. Two-hundred participants (77% female; BMI approximately 31kg/m^2; age approximately 44 years) followed an energy-restricted diet in a one-year trial (six-month weight loss and six-month weight maintenance); subjects were randomized to one of four intervention groups. Subjects in three of the groups were given supplies of commercially available food that was low in energy (100 kcal per serving) and fat (less than 4g per serving). Subjects in these groups were instructed to consume daily: One serving of soup (one-soup group), two servings of soup (two-soup group), or two servings of dry snack foods (two-snack group). Subjects in the fourth group were not provided with any specific food to consume (comparison group). Three-day diet records were completed at baseline and one, two, six and 12 months. Height and weight were measured by study personnel. One hundred forty-seven participants (74%) completed the one-year trial. Reported energy intake decreased significantly from baseline to six months and increased slightly at 12 months ($P<0.005$). There were NS differences in reported energy intake among the intervention groups at any time-points. All four groups showed significant weight loss at six months that was well-maintained at 12 months. The magnitude of weight loss, however, differed by group ($P<0.006$). At one year, weight loss in the comparison (8.1±1.1kg) and two-soup (7.2±0.9kg) groups was significantly greater than that in the two-snack group (4.8±0.7kg); weight loss in the one-soup group (6.1±1.1kg) did not differ significantly from other groups. The authors concluded that on an energy-restricted diet, consuming two servings of low energy-dense soup daily led to 50% greater weight loss than consuming the same amount of energy as high energy-dense snack food.

Flood and Rolls, 2007 (positive quality), a randomized crossover trial conducted in the US, examined the effects of consuming different forms of a low-energy dense soup on subsequent test meal intake and total energy intake at the meal. Participants were 60 normal weight adults (50% female; age 20-46 years) who went to the laboratory for lunch once a week for five weeks. Each week subjects participated in one of five test sessions, the order of which was randomly assigned: No preload or one of four soup preloads (females: 350 ml; males 475ml) with the same energy density (1.4kJ per gram), but prepared differently (broth and vegetables served separately, chunky vegetable soup, chunky-pureed vegetable soup or pureed vegetable soup). A test meal was consumed ad libitum 15 minutes after the soup was served. Results showed that consuming soup significantly reduced test meal intake ($P<0.0001$) and total meal energy intake (preload and test meal; $P<0.0001$) compared to having no soup. When soup was consumed, subjects reduced meal energy intake by 20% (134±25kcal). The type of soup had NS effect on test meal intake or total meal energy intake. The authors concluded that consuming a preload of low-energy-dense soup, in a variety of forms, is one strategy for moderating energy intake in adults.

Bertrais et al, 2001 (neutral quality), a cross-sectional study conducted in France, assessed the impact of soup consumption on nutrient intake and nutritional indicators in adults who were participants in the SU.VI.MAX cohort. Dietary intake data was analyzed for a sub-sample of men (N=2,188; age 45 to 60 years) and women (N=2,849; age 35 to 60 years), who completed twelve 24-hour diet records over a two-year period (N=60,444 total records); analysis utilized average intakes for the total records for each subject. Height and weight were measured by study personnel. Respondents were divided into three groups based on soup consumption every six days:

1. Occasional/non-consumers (zero to two times)
2. Regular consumers (three to four times)
3. Heavy consumers (five to six times).

Mean energy intake was lower in heavy consumers than in occasional/non-consumers, but the difference was significant only for women (1,784±37kcal vs. 1,831±12kcal, respectively; P=0.02). 92% of soups were consumed at dinner. Soup consumers presented lower energy intake at dinner than occasional/non-consumers (P≤10-6 for men and women). In men, energy intakes at dinner for heavy and occasional/non-consumers were 756±22 and 909±8kcal, respectively. In women, energy intakes at dinner for heavy and occasional/non-consumers were 548±3 and 655±6kcal, respectively. In men, a higher frequency of BMI>27kg/m^2 was found in occasional/non-consumers of soup; conversely, a higher frequency of BMI between 23 and 27kg/m^2 was found in regular consumers of soup and a higher frequency of BMI<23kg/m^2 was found in heavy consumers. For women, an association was found between occasional/non-consumers and BMI>25kg/m^2 and between heavy consumers and BMI<22kg/m^2. The authors concluded that consumption of soup may be beneficial in weight reduction programs.

Study	Study Design	Liquid	Solid	Outcome	Results
Chen, 2009 **Rating:**	Prospective cohort study (PREMIER): Intake data the average of two 24-hour recalls conducted at zero, six and 18 months.	Liquid calories (beverages).	Solid calories.	(1) Body weight Δ (2) Weight loss.	Liquid: (+) body weight Δ ↓ in liquid calorie intake had stronger effect on weight loss than ↓ in solid calorie intake.
DiMeglio, 2000 **Rating:**	Randomized crossover trial with two, four-week interventions with daily consumption of test foods.	Caffeine-free soda.	Jelly beans.	(1) Daily energy intake (2) Body weight.	Daily energy intake higher with liquid load than solid load. Body weight and BMI significantly ↑ only during liquid load.
Mourao, 2007 **Rating:**	Crossover dietary challenge with matched preloads followed by ad lib lunch	Watermelon juice. Milk. Coconut milk.	Watermelon. Cheese. Coconut meat.	Daily energy intake.	Daily energy intake was ↑ on days the liquid forms were ingested regardless of primary energy source.
Mattes, 2009 **Rating:**	Randomized crossover trial with apple preload followed by ad lib lunch.	Apple juice.	Apple. Applesauce.	Daily energy intake.	Ø between food form and daily energy intake.
Flood-Obbagy, 2009 **Rating:**	Randomized crossover trial with no preload or apple preloads followed by ad lib lunch.	Apple juice with added fiber. Apple juice without added fiber.	Apple. Applesauce.	Energy intake of: (1) preload and test meal.	Apple and applesauce: ↓ total meal energy intake Juice (with or without added fiber): Did not ↑ total meal

					energy intake compared with no preload.
Moorhead, 2006 **Rating:**	Randomized crossover trial with standardized breakfast and test lunches followed by ad lib meal later in the day.	Carrot nutrients (formulated to give same energy, major nutrients, and portion weight).	Carrots. Blended carrots.	Energy intake of: (1) ad lib meal (2) remainder of day.	Whole and blended carrots result in significantly ↓ subsequent intakes.
Stull, 2008 **Rating:**	Randomized crossover trial with meal replacement preload followed by ad lib breakfast.	Meal replacement beverage.	Meal replacement bar.	Energy intake of: (1) test meal.	Energy intake ↑ after the liquid vs. solid meal replacement product.
Almiron-Roig, 2004 **Rating:**	Crossover trial with preload followed by ad lib lunch.	Regular cola.	Fat-free cookies.	Energy intake of: (1) test meal (2) breakfast + preload plus test meal.	Ø on energy intakes during test meal or B+P+TM.
Tsuchiya, 2006 **Rating:**	Crossover trial with peach preload followed by ad lib lunch.	Peach yogurt in liquid form. Peach syrup and water. Milk-based peach beverage.	Semisolid peach yogurt with peach pieces.	Energy intake of: (1) test meal (2) breakfast + preload plus test meal.	Ø on energy intakes during test meal or B+P+TM.
Rolls, 2005 **Rating:**	RCT: one-year weight loss / maintenance trial.	One serving soup per day. Two servings soup per day.	Two snack foods per Control.	(1) Daily energy intake (2) Weight loss.	No difference in daily energy intake Consuming two servings soup per day led to ↑ weight loss than consuming same amount of energy from two snack foods per day.
Flood, 2007 **Rating:**	Randomized crossover trial with no preload or soup preload followed by ad lib lunch.	Soup (four versions).	No soup.	Energy intake of: (1) Test meal (2) Preload and test	Soup preload significantly ↓ test meal and total meal energy intake.

				meal.	
Bertrais, 2001 **Rating:**	Cross-sectional study (SU.VI.MAX Cohort): Average of 12, 24-hour diet records from 5,037 participants.	Regular soup consumers. Heavy soup consumers.	Occasional/ non-consumers of soup.	(1) Daily energy intake (2) Dinner energy intake (3) BMI.	Heavy soup consumers: (-) Daily energy intake (women), (-) Energy intake at dinner, (-) BMI.

Research Design and Implementation Rating Summary
For a summary of the Research Design and Implementation Rating results, click here.

Worksheets

Almiron-Roig E, Flores SY, Drewnowski A. No difference in satiety or in subsequent energy intakes between a beverage and a solid food. *Physiol Behav.* 2004 Sep 30; 82 (4): 671-677.

Bertrais S, Galan P, Renault N, Zarebska M, Preziosi P, Hercberg S. Consumption of soup and nutritional intake in French adults: consequences for nutritional status. *J Hum Nutr Diet.* 2001;14(2):121-8.

Chen L, Appel LJ, Loria C, Lin PH, Champagne CM, Elmer PJ, Ard JD, Mitchell D, Batch BC, Svetkey LP, Caballero B. Reduction in consumption of sugar-sweetened beverages is associated with weight loss: the PREMIER trial. *Am J Clin Nutr.* 2009 May;89(5):1299-306. Epub 2009 Apr 1.

DiMeglio DP, Mattes RD. Liquid versus solid carbohydrate: effects on food intake and body weight. Int J Obes Relat Metab Disord. 2000 Jun;24(6):794-800.

Flood JE, Rolls BJ. Soup preloads in a variety of forms reduce meal energy intake. Appetite. 2007 Nov;49(3):626-34. Epub 2007 Apr 14.

Flood-Obbagy JE, Rolls BJ. The effect of fruit in different forms on energy intake and satiety at a meal. Appetite. 2009 Apr;52(2):416-22. Epub 2008 Dec 6. PubMed PMID: 19110020; PubMed Central PMCID: PMC2664987.

Mattes RD, Campbell WW. Effects of food form and timing of ingestion on appetite and energy intake in lean young adults and in young adults with obesity. J Am Diet Assoc. 2009 Mar;109(3):430-7.

Moorhead SA, Welch RW, Barbara M, Livingstone E, McCourt M, Burns AA, Dunne A. The effects of the fibre content and physical structure of carrots on satiety and subsequent intakes when eaten as part of a mixed meal. *Br J Nutr.* 2006; 96(3): 587-595.

Mourao DM, Bressan J, Campbell WW, Mattes RD. Effects of food form on appetite and

energy intake in lean and obese young adults. *Int J Obes* (Lond). 2007 Nov;31(11):1688-95. Epub 2007 Jun 19.

Rolls BJ, Roe LS, Beach AM, Kris-Etherton PM. Provision of foods differing in energy density affects long-term weight loss. *Obes Res.* 2005 Jun;13(6):1052-60.

Stull AJ, Apolzan JW, Thalacker-Mercer AE, Iglay HB, Campbell WW. Liquid and solid meal replacement products differentially affect postprandial appetite and food intake in older adults. *J Am Diet Assoc*. 2008 Jul;108(7):1226-30.

Tsuchiya A, Almiron-Roig E, Lluch A, Guyonnet D, Drewnowski A. Higher satiety ratings following yogurt consumption relative to fruit drink or dairy fruit drink. *J Am Diet Assoc.* 2006 Apr;106(4):550-7.